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Environment of deposition of the sandstones of Lower Vindhyans of parts of Durg district, Madhya Pradesh, India

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ABSTRACT

Present paper attempts to establish the environment of deposition of the sandstones belonging to the Chandarpur Group exposed in parts of the Durg district, Madhya Pradesh (India). Grain size and shape analyses of the sandstones are carried out. Vertical variations of the different grain size statistics of the fluvial and beach sediments are also studied. A multivariate linear discriminant technique was adopted for discriminating the sediments of these two environments. The palaeocurrents are towards north, northeast and southeast.

Petrographic studies and provenance analysis of the sandstones show that the beach environment is richer in quartz and poorer in matrix as compared to the fluvial ones. The sandstones have been clearly differentiated with the help of multivariate discriminant analysis using thin section modal constituents like quartz, feldspars, iron oxide, matrix, etc. Results of the lithostratigraphic, grain size and petrographic studies fairly tally with each other suggesting that the sandstones under study were deposited under two very different fluvial and beach environments.

INTRODUCTION

The study area is a part of the Chhattisgarh basin in the state of Madhya Pradesh, India, and falls in the toposheet numbers 64 H/5 and 64 H/6. It lies nearly 30 km south of Durg, an important city of south-eastern Madhya Pradesh (Fig. 1).

GEOLOGY OF THE AREA

Medlicott (1867), Blanford (1870), King (1885), Dutt (1964) and others carried out the geological mapping of the area in the past. The huge succession of sedimentary rocks of the area was named as the Chhattisgarh Supergroup (Fig. 2). These rocks occupy intermediate position between the Cuddapah Supergroup below and the Vindhyan Supergroup above.

The rocks of the Chhattisgarh Supergroup have been divided into a lower Chandarpur Group and an upper Raipur Group. The Chandarpur Group is arenaceous in nature, whereas the Raipur Group is calcareous and argillaceous. The lithostratigraphy of the study area is presented in Table 1.

ENVIRONMENT OF DEPOSITION

Sedimentological, textural and petrographic analyses of the sandstones of the Chandarpur Group were carried out for establishing their environment of deposition. Two distinct lithofacies, A and B, have been identified on the basis of sedimentary structures, size of clasts, palaeocurrents and lithological characters.

Lithofacies 'A'

The colour of the sandstones of this facies varies from dark brown to red with an indigo tinge at times. It is characterized by the presence of horizontal to slightly inclined conglomerates with profuse cross-beds. A typical section of this lithofacies is shown in Fig. 3 where a general fining up sequence can be seen. The repeating cyclothems are of the order of 1.5 to 2.5 m thickness.

Many facies-states within the lithofacies 'A' of the area have been identified. They closely resemble to the facies-states in the sandstones of

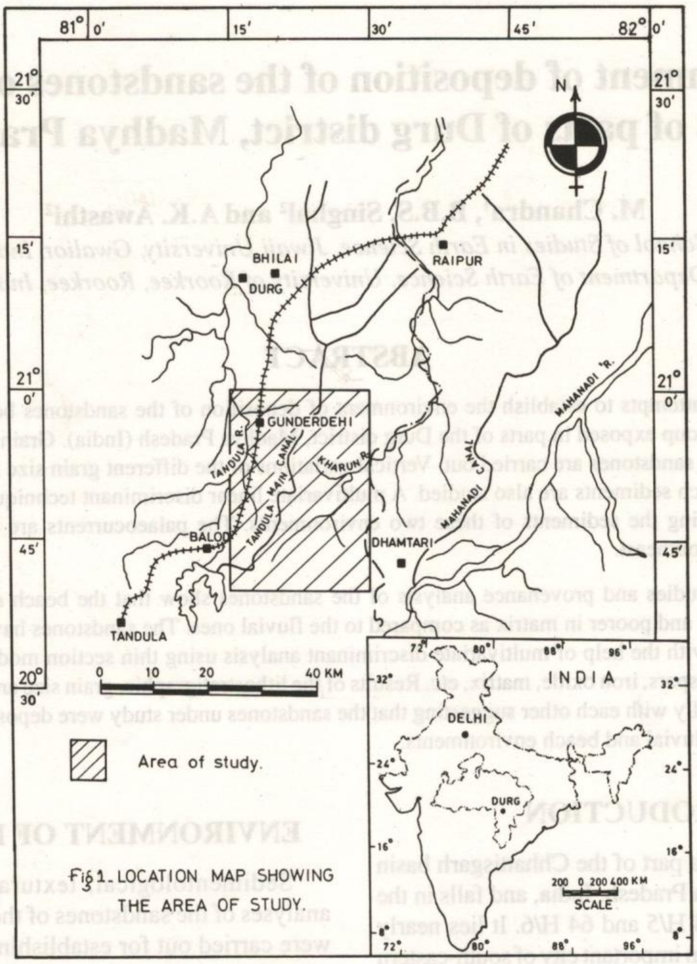

Fig 1. LOCATION MAP SHOWING THE AREA OF STUDY.

Fig. 1: Location map of the study area.

Table 1: Stratigraphy of Chattisgarh Supergroup.

Rock units	Age	Formation	Thickness	Lithology
	Recent	Alluvium	10-30 m	Gravel, silt and clay
Raipur	800 Ma	Gunderdehi Formation	100-150 m	Brown calcareous splintery shales
Group		Charmuria Formation	150-180 m	Grey to buff, fine grained, thin bedded limestones
		---Unconformity---		
Chandarpur	1000-900 Ma	Chandarpur Formation	30-100 m	Medium grained feldspathic sandstones with minor shales, quartzites and conglomerates
		---Unconformity---		
Archaeans				Granites, dolerites, etc.

the Jodhpur Group in Rajasthan, India as described by Awasthi (1979). The facies-states observed in the lithofacies A are massive or weakly bedded conglomerates (Cg), horizontally bedded sandstones (Sh), cross-bedded sandstones (Sc) and erosional surfaces (E).

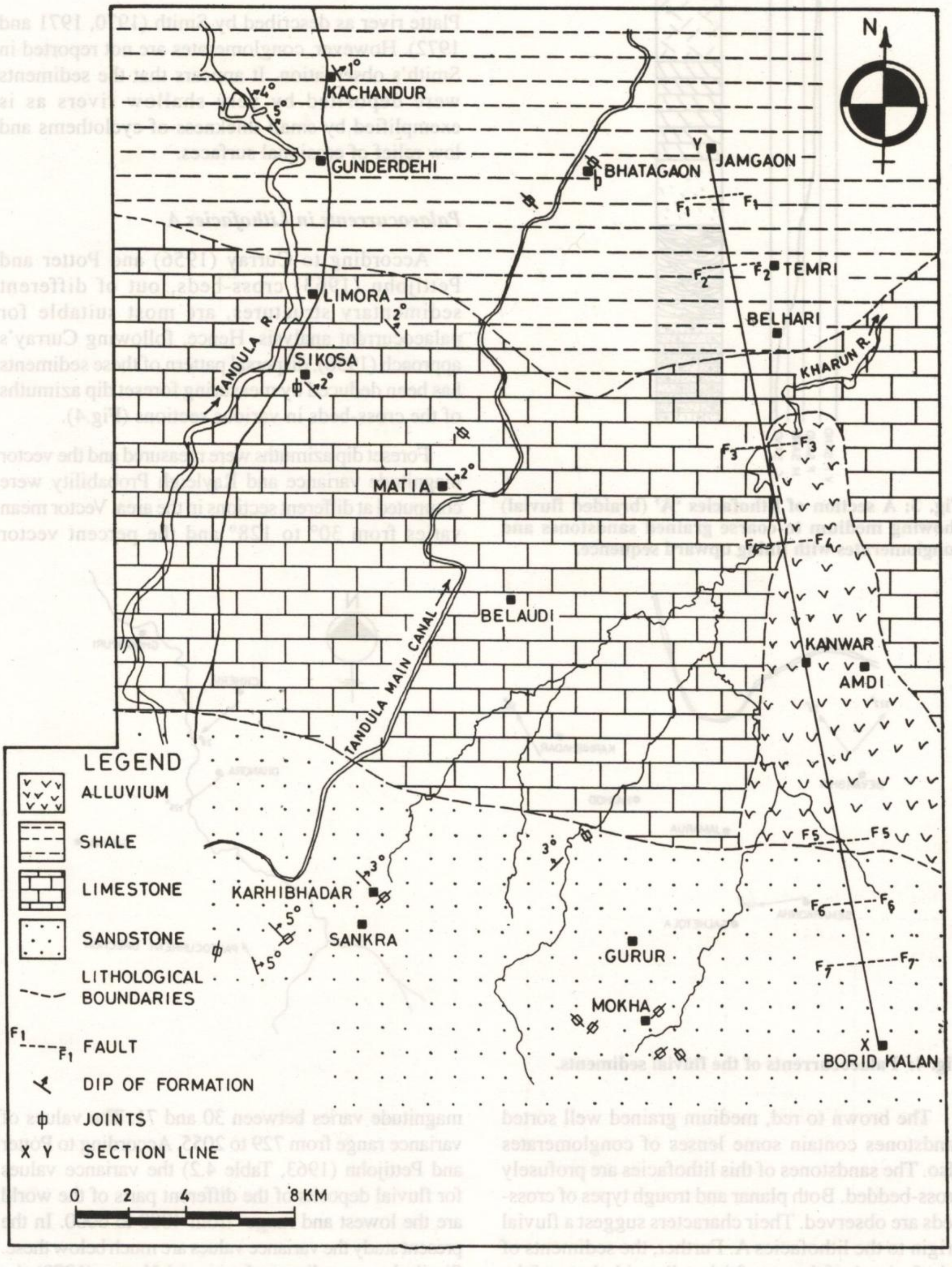

Fig. 2: Geological map of the study area.

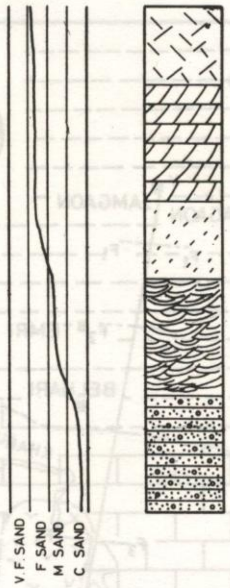

Fig. 3: A section of lithofacies 'A' (braided fluvial) showing medium to coarse grained sandstones and conglomerates with fining upward sequence.

Platte river as described by Smith (1970, 1971 and 1972). However, conglomerates are not reported in Smith's observation. It appears that the sediments were deposited by very shallow rivers as is exemplified by small thickness of cyclothems and low relief of erosional surfaces.

Palaeocurrents in Lithofacies A

According to Curray (1956) and Potter and Pettijohn (1963) cross-beds, out of different sedimentary structures, are most suitable for palaeocurrent analysis. Hence, following Curray's approach (1956), dispersal pattern of these sediments has been deduced by measuring foreset dip azimuths of the cross-beds in various sections (Fig.4).

Foreset dip azimuths were measured and the vector magnitude variance and Rayleigh Probability were computed at different sections in the area. Vector mean varies from 30° to 128° and the percent vector magnitude varies between 30 and 71. The values of variance range from 729 to 2055. According to Potter and Pettijohn (1963, Table 4.2) the variance values for fluvial deposits of the different parts of the world are the lowest and range from 4000 to 6000. In the present study the variance values are much below these. Similarly, according to Long and Young (1978) the

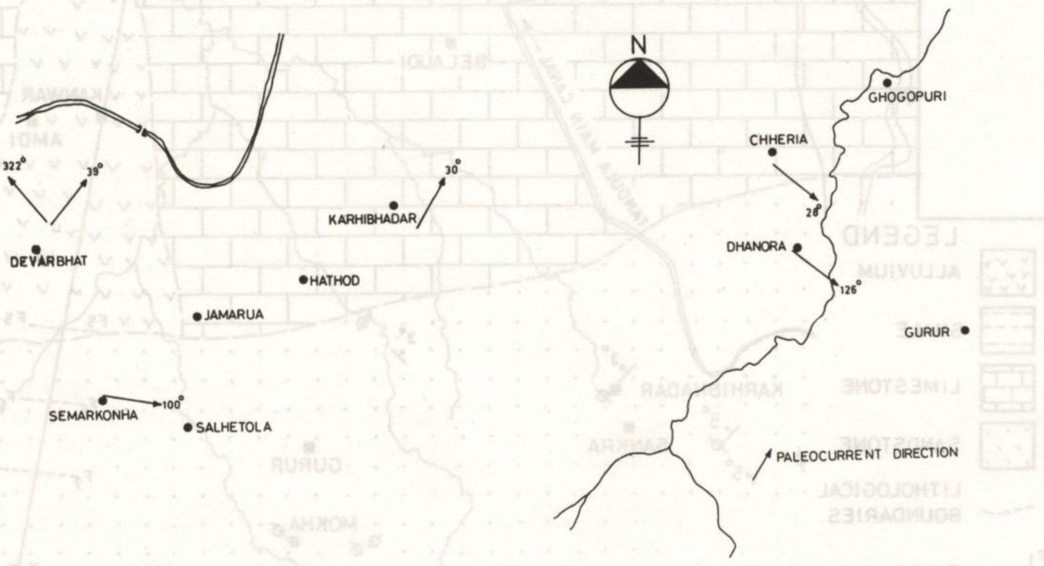

Fig. 4: Palaeocurrents of the fluvial sediments.

The brown to red, medium grained well sorted sandstones contain some lenses of conglomerates also. The sandstones of this lithofacies are profusely cross-bedded. Both planar and trough types of cross-beds are observed. Their characters suggest a fluvial origin to the lithofacies A. Further, the sediments of lithofacies A of the area fairly tally with those of the variance values of fluvial pattern are below 4000 and those of marine ones are more than 4000. Hence, the cross-bedded sandstones of the Lithofacies A can be interpreted as fluvial.

Following the graphical method of Reiche, Raup and Miesh (Selley, 1968) the palaeocurrent directions were determined and plotted on the map to know the dispersal pattern (Fig. 4). From the plotting it appears that the regional variation of palaeocurrents is towards N, NE and SE. It can be inferred that the source of these sediments lies somewhere at the south-western part of the area.

Lithofacies B

The sediments of this lithofacies are rarely exposed in the area. The sandstones of this lithofacies are light red to flesh red in colour. They are medium to fine grained, well sorted and show low-angled cross-beds and dunes. They also exhibit horizontal stratification and at places wavy laminations. Based on McKee (1957), Kukal (1970), Reineck and Singh (1973) and Awasthi (1979), the sandstones of the lithofacies B can be interpreted to be of beach environment.

TEXTURAL ANALYSES

The textural analyses of the sandstones of the Chandarpur Group were carried out to investigate their environments of deposition. Grain size, sphericity and roundness of the quartz grains, the essential constituent of the sandstones were determined and considered for the study. The moment method was used to measure the grain size statistics. Geometric mean of the maximum and minimum to intercept diameters were used as per Middleton's approach (1962) in the form of the following equation:

$$X = -\log_2 (k/m \times n)$$

where,

X is the size of the grain in dia scale,
m is the largest intercept across the grain,
n is the largest intercept perpendicular to the maximum diameter m of the grain, and
k is the factor which reduces the micrometer readings for m and n, in millimeters.

For grain sphericity, the two dimensional formula as used by Middleton (1962) has been employed in the present study.

$$S_{ph} = m/n, \text{ where } m>n$$

Roundness values of the grains have been visually estimated using Powers' chart (1953). A computer programme by Parkash (1969) was used to find out the various statistics for grain size, sphericity and roundness. The mean grain size of the sandstones varies from 0.46 to 2.44 dia and the variance ranges from 0.11 to 0.53; the values of mean sphericity range between 0.616 and 0.715 and the mean roundness range from 1.66 to 4.68.

Textural parameters, especially the grain size statistics, obtained from thin section data have been subjected to graphical method to determine the environment of deposition of the sandstones of two lithofacies. Following Sindowski (1967) and Visher (1969), representative cumulative frequency curves for various samples of fluvial (Fig. 5) and beach facies (Fig. 6) were drawn. The frequency curves for fluvial sediments show two to three segments, whereas the beach sediments indicate polysegmented curves.

Multivariate Approach

From textural parameters multivariate linear discriminant function analyses are carried out to distinguish the environments of deposition of the sandstones of the area. The multivariate linear discriminant analysis takes into account simultaneously many variables to distinguish between similar looking objects. Six variables, viz., grain size, standard deviation of grain size, skewness, kurtosis, grain sphericity, standard deviation of sphericity and roundness were taken into account in the present study. The discriminant function is defined as:

$$R = \sum_{i=1}^{6} bi.xi$$

where xi(i=1,...,6) are the above stated variables and bi are the constants which are selected in such a way so as to maximize the distance between the two clusters and minimize the spread within the cluster of points for fluvial and beach sediments formed in a multidimensional space. A discriminant index D_I is calculated to differentiate between the two environments. The value of $R>D_I$ indicates one

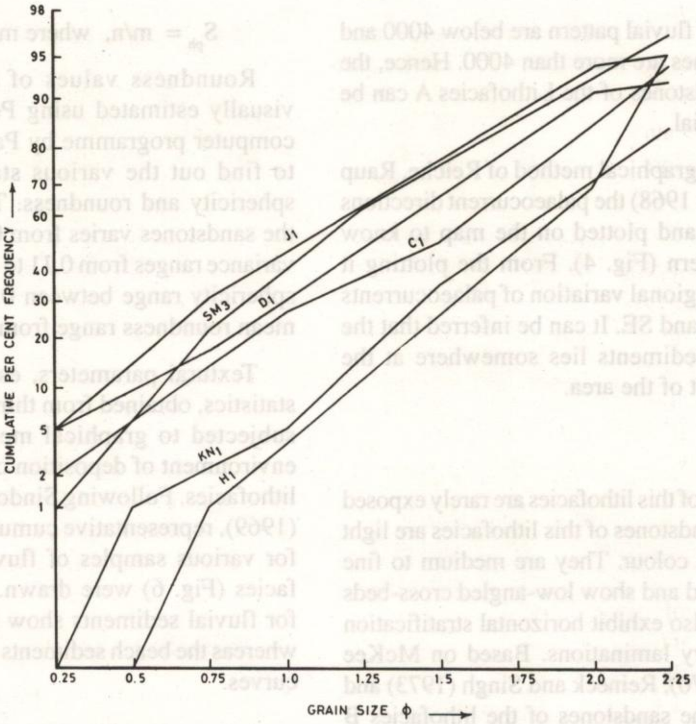

Fig. 5: Cumulative frequency curves of grain size for some representative samples of the sandstones of fluvial facies.

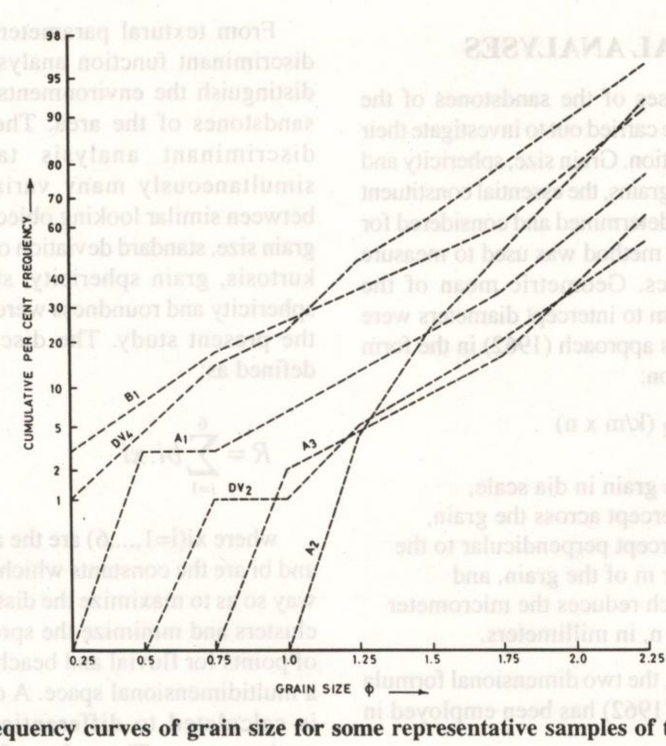

Fig. 6: Cumulative frequency curves of grain size for some representative samples of the sandstones of beach facies.

environment while the value of R<D_1 the other environment. Mathematical account of this technique is given by Miller and Kahn (1962) and Krumbein and Graybill (1965).

The textual data in the present study was run on a computer programme developed by Sinvhal (1979). Table 2 shows the data in the form of variables, discriminant constants and percent contribution of variables.

Table 2: Values of Discriminant Variables, constants and percent contribution of variables

Variables (xi)	Fluvial vs. Beach Discriminant Constants (bi)	Percent Contribution of Variables
m_1	0.8560	-8.3947
m_2	7.3580	10.2512
g_1	1.1352	4.6816
g_2	13.1268	7.1337
ms_2	-48.2582	-1.3344
mr_1	-2.3345	87.5627

The discriminant function (R) has been calculated and it is observed that for fluvial sediments, R is greater than 0.0888 and for beach sediments R is less than 0.0888. It has been found that with the application of this technique nearly 84% of the fluvial samples and 66% of the beach samples have been clearly differentiated. Mean roundness has been found to be the discriminating factor.

Vertical Variation in mean size

Vertical variation in grain size were studied with a view to establish this variation with the earlier interpreted fluvial and beach facies environments. It is observed in these profiles (Fig. 7) that in general, the grains fine upwards in the sediments of both the facies. However, the beach sediments appear to be better sorted as compared to fluvial sediments.

PETROGRAPHIC APPROACH

In order to establish the influence of depositional environment on the petrography of the sandstones,

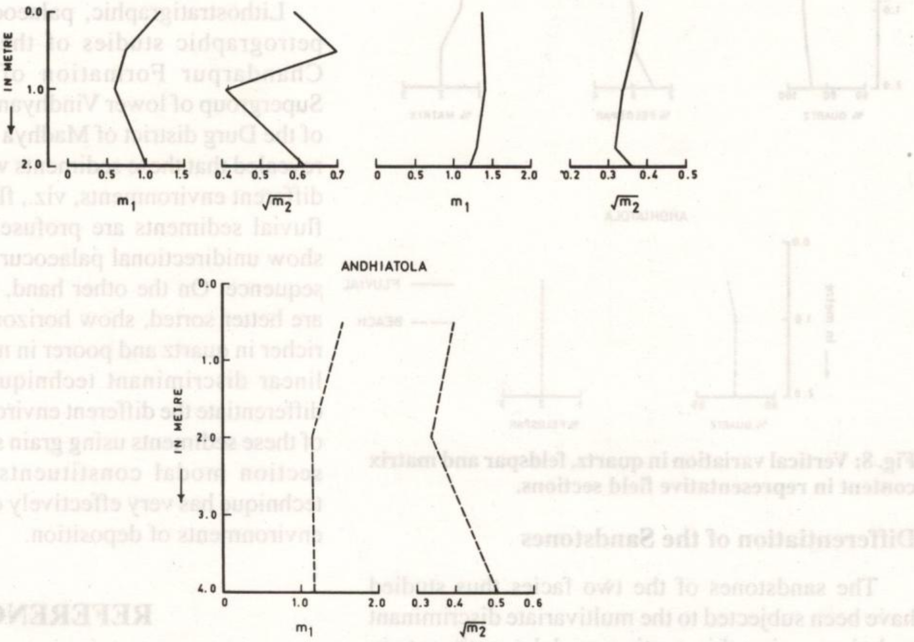

Fig. 7: Vertical variation in the mean grain size (m_1) and standard deviation ($\sqrt{m_2}$) in representative sections.

mean grain size against the percentage of quartz and matrix have been plotted (Fig. 8). These plots show that for a given grain size, sandstones of beach environment are richer in quartz and poorer in matrix as compared to the fluvial ones. Similarly, the plots indicate that, in general, quartz increases vertically upwards and feldspar increases upwards in fluvial sediments, but it remains almost constant in case of beach sediments. On the other hand, the matrix decreases upwards in fluvial sediments, whereas the beach deposits are almost devoid of matrix.

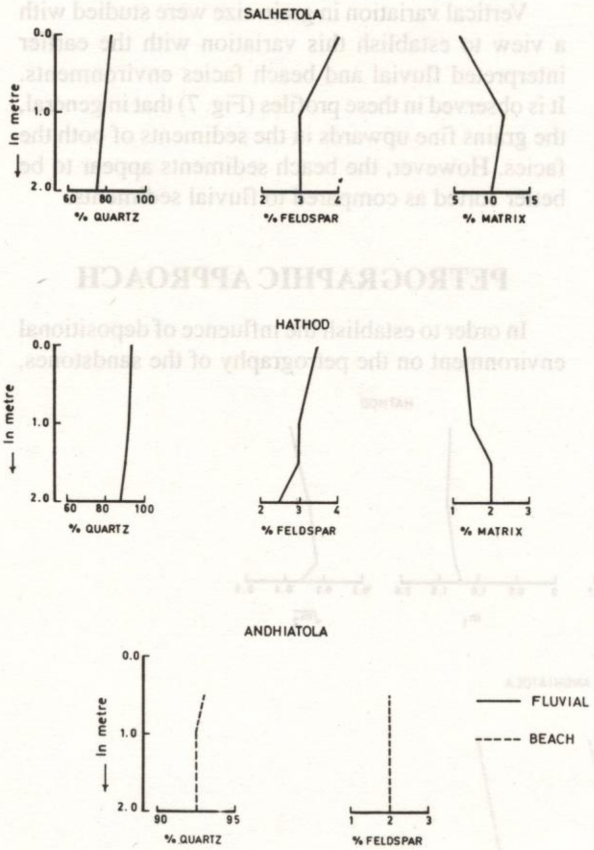

Fig. 8: Vertical variation in quartz, feldspar and matrix content in representative field sections.

Differentiation of the Sandstones

The sandstones of the two facies thus studied have been subjected to the multivariate discriminant technique using thin section modal constituents in order to differentiate their environment of deposition. The technique has been fruitful in discriminating the sediments of two different environments. Table 3 shows the discriminant constants, variables and discriminant criteria. The most effective contributors or variables in this discrimination are quartz, feldspar and matrix.

Table 3: Values of discriminant variables, constants and percent contribution of variables for discrimination between the sandstones of two different environments.

Variables	Discriminant Constants	Percent Contribution
Quartz	-2.0350	259.9171
Feldspar	0.5437	10.7420
Mica	-1.9253	-23.8366
Iron Oxide	-2.0381	-30.6481
Cement	-2.0589	-3.5049
Matrix	-1.6222	112.7234

The discriminant function (R) has been calculated and it is observed that for the sandstones of fluvial environment R is greater than 194.8199 and for the sandstones of beach environment R is less than 194.8199.

CONCLUSIONS

Lithostratigraphic, palaeocurrent, textural and petrographic studies of the sandstones of the Chandarpur Formation of the Chhattisgarh Supergroup of lower Vindhyan age exposed in parts of the Durg district of Madhya Pradesh (India) have revealed that these sediments were deposited in two different environments, viz., fluvial and beach. The fluvial sediments are profusely cross-bedded and show unidirectional palaeocurrents and a fining up sequence. On the other hand, the beach sediments are better sorted, show horizontal laminations, and richer in quartz and poorer in matrix. A multivariate linear discriminant technique was employed to differentiate the different environments of deposition of these sediments using grain size statistics and thin section modal constituents as variables. The technique has very effectively differentiated the two environments of deposition.

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